(12) UK Patent Application (19) GB (11) 2 278 971 (13) A

(43) Date of A Publication 14.12.1994

(21) Application No 9401632.6

(22) Date of Filing 28.01.1994

(30) Priority Data
(31) 05135693 (32) 07.06.1993 (33) JP

(51) INT CL[5]
H04B 10/24 10/02, H04Q 11/00

(52) UK CL (Edition M)
H4B BK2 BK24 BN
G2J JGEE
U1S S2208

(56) Documents Cited
GB 1461362 A US 5077813 A US 4551829 A

(58) Field of Search
UK CL (Edition M) G2J JBSS1 JGEE, H4B BK2 BK24 BN
INT CL[5] H04B 10/02 10/24, H04Q 11/00

(71) Applicant(s)
Fujitsu Limited

(Incorporated in Japan)

1015 Kamikodanaka, Nakahara-ku, Kawasaki-shi, Kanagawa 211, Japan

(72) Inventor(s)
Masaaki Takahashi
Aya Suzuki

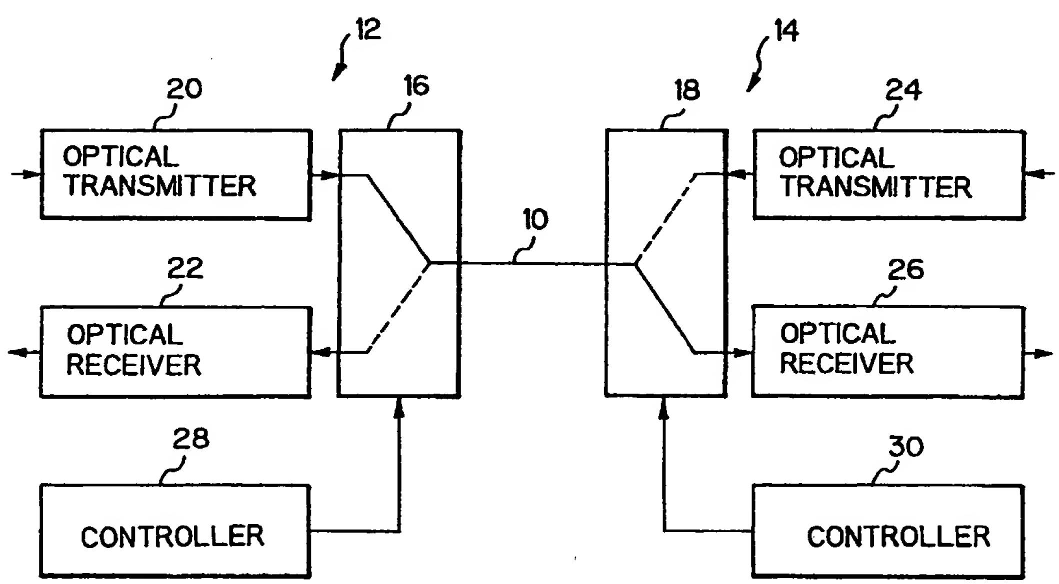
(74) Agent and/or Address for Service
Haseltine Lake & Co
Hazlitt House, 28 Southampton Buildings, Chancery Lane, LONDON, WC2A 1AT, United Kingdom

(54) **Bidirectional optical communications**

(57) In order to reduce insertion loss and to solve the problem of reflection associated with use of a coupler, an optical switch 16, 18 is used to selectively connect an optical transmitter 20, 24 or an optical receiver 22, 26 to an optical fiber 10 or a passive optical network (PON) (56, fig 4) in a time compression multiplexing (TCM) system or a time division multiple access (TDMA) system.

The optical switch (fig 3) may include a prism (40) movable between two points by an electromagnetic drive mechanism, and lenses (44, 46, 50) at the inputs and outputs.

Fig. 1



GB 2 278 971 A

Fig. 1

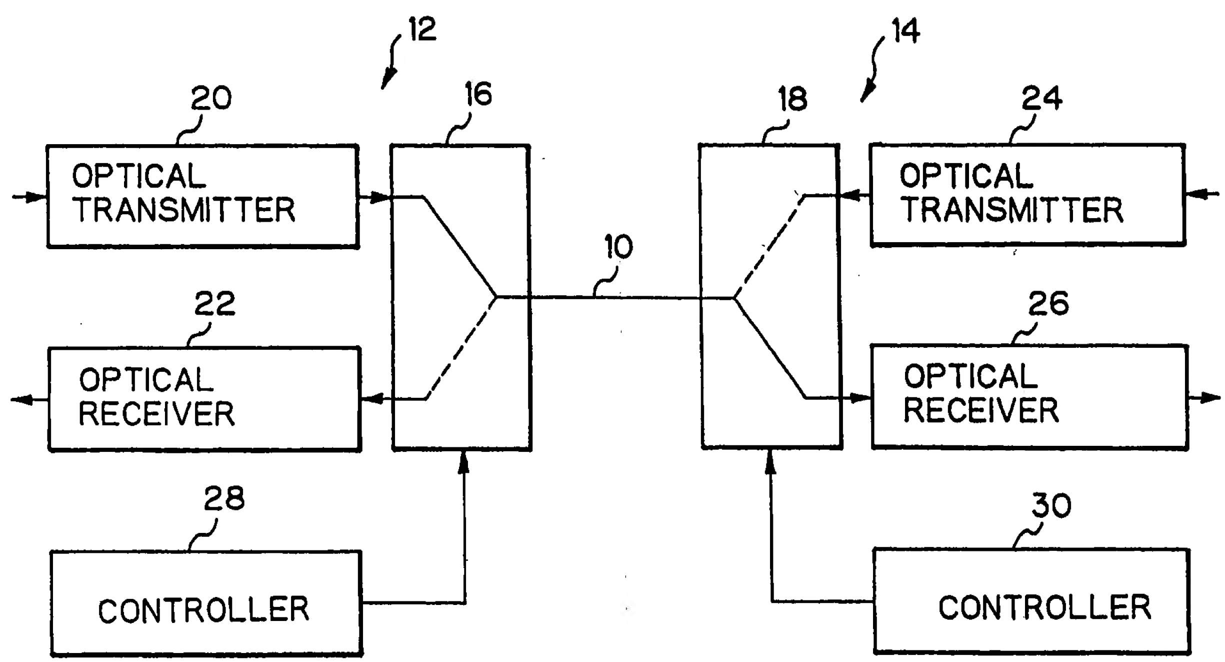

12
14
20
16
18
24
OPTICAL TRANSMITTER
OPTICAL TRANSMITTER
10
22
26
OPTICAL RECEIVER
OPTICAL RECEIVER
28
30
CONTROLLER
CONTROLLER

Fig. 2A

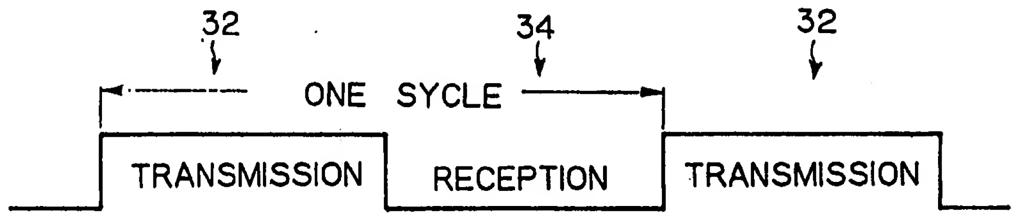


Fig. 2B

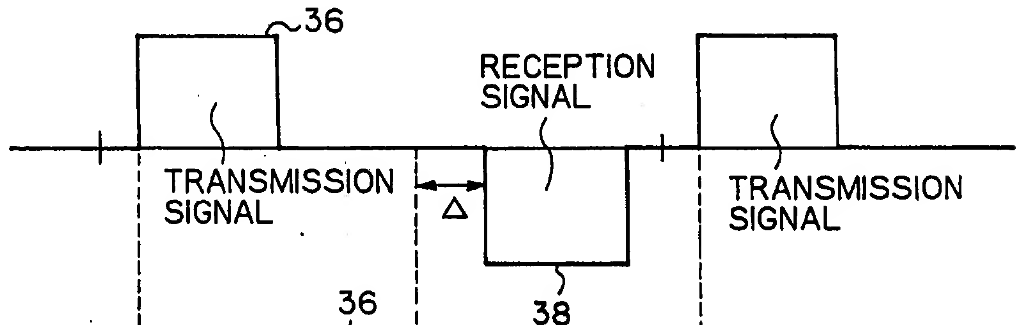


Fig. 2C

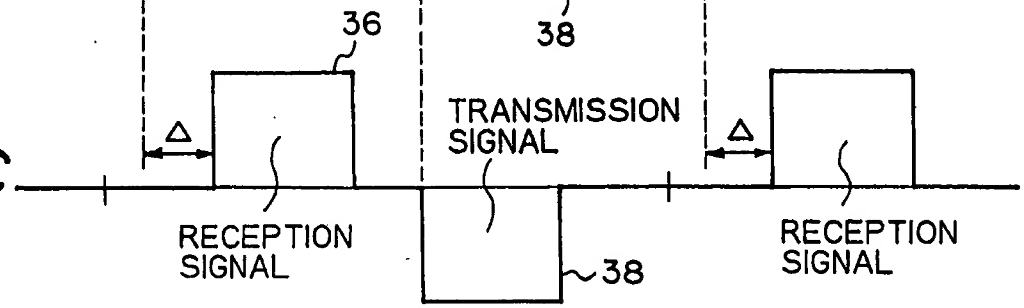


Fig. 2D

Fig. 3

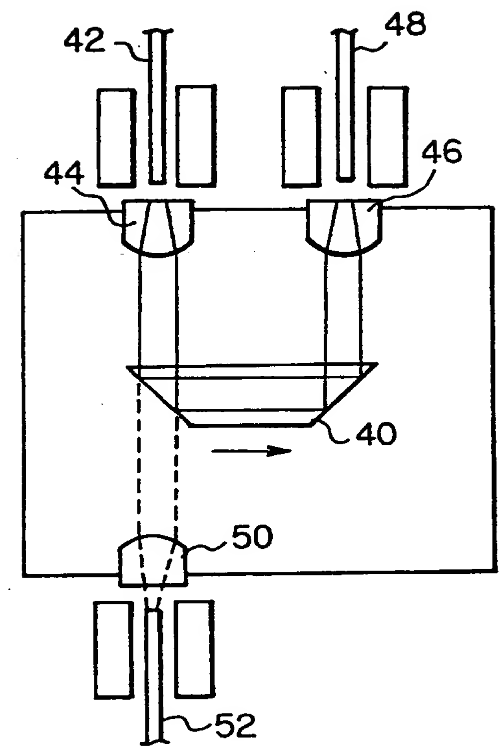


Fig. 4

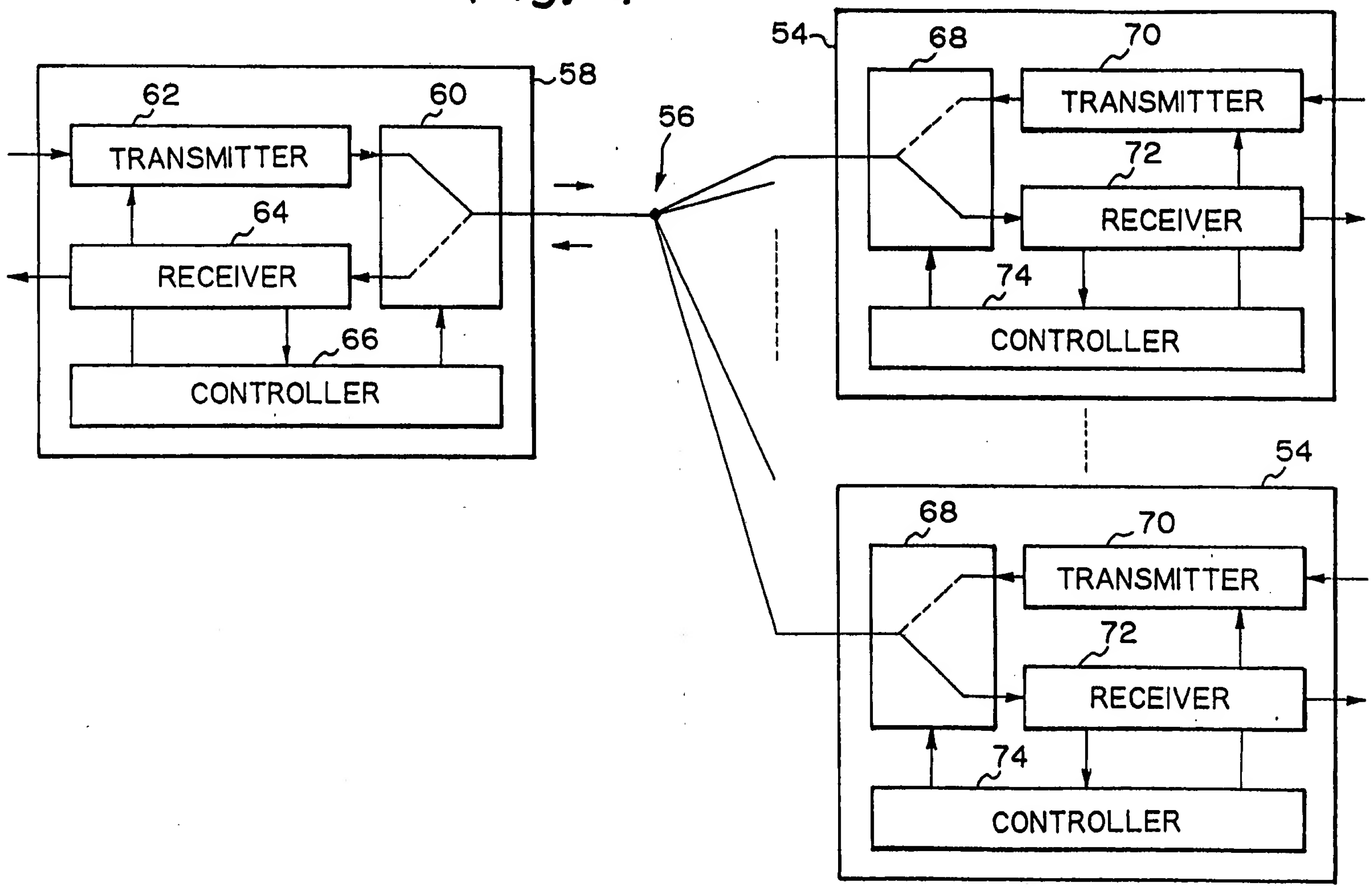

58
62
TRANSMITTER
60
64
RECEIVER
66
CONTROLLER
56
54
68
70
TRANSMITTER
72
RECEIVER
74
CONTROLLER
54
68
70
TRANSMITTER
72
RECEIVER
74
CONTROLLER

Fig.5A Fig.5B Fig.5C Fig.5D Fig.5E Fig.5F

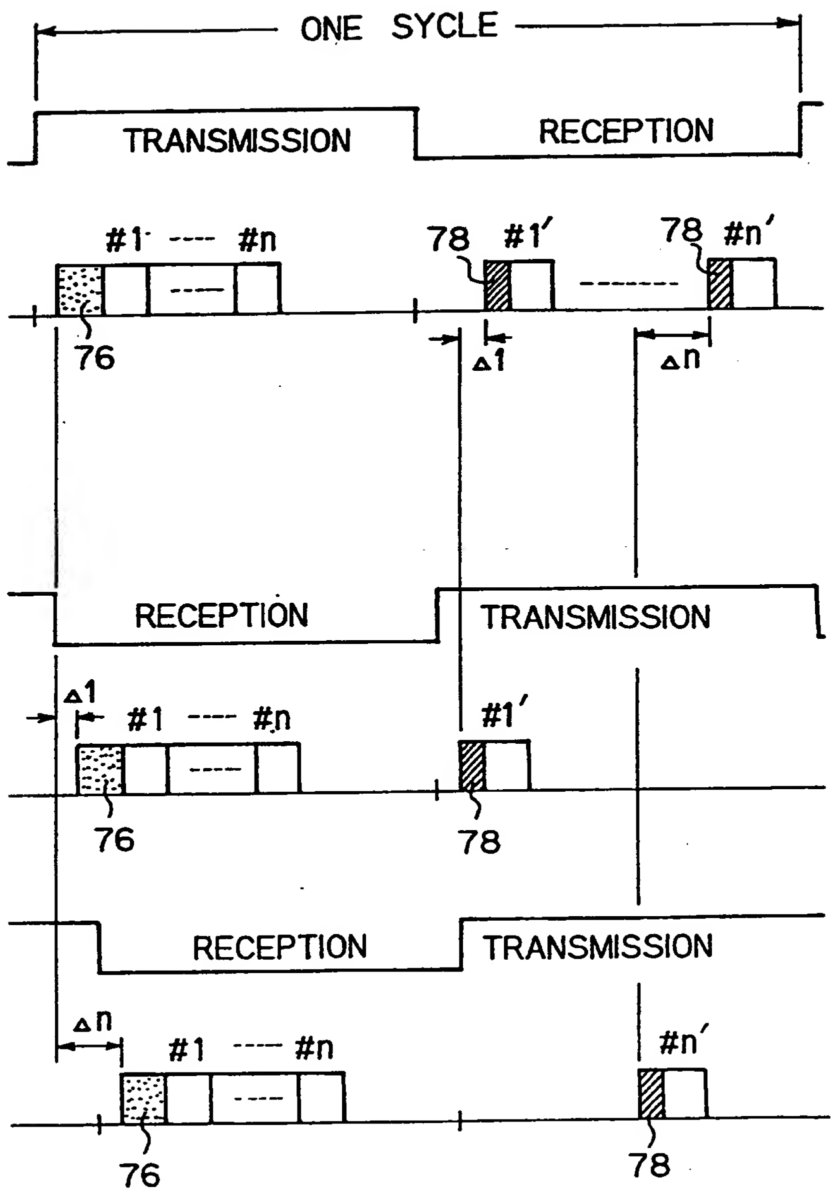
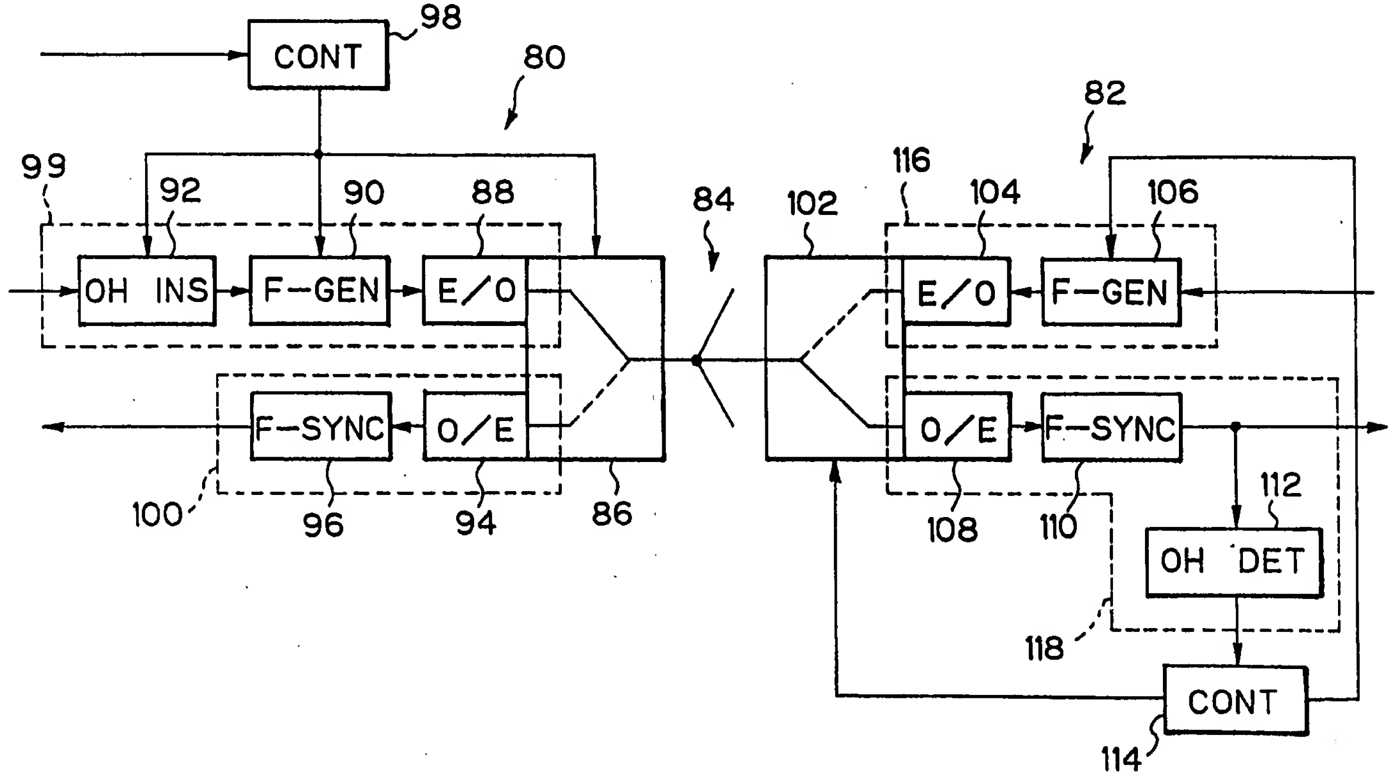


Fig. 6


CONT
98
80
82
99
92
90
88
84
102
116
104
106
OH INS
F-GEN
E/O
E/O
F-GEN
F-SYNC
O/E
O/E
F-SYNC
100
96
94
86
108
110
112
OH DET
118
CONT
114

TWO-WAY TRANSMISSION SYSTEM USING SINGLE OPTICAL PATH

The present invention relates to a two-way transmission system using a single optical path, such as a time compression multiplexing (TCM) system via a single optical fiber and a time division multiple access (TDMA) system via a passive optical network (PON) wherein a single optical fiber emerging from an exchange is fanned out at suitable points to feed a number of individual customers.

In a two-way transmission system using a single optical path, optical couplers are usually used, at the ends of the optical path, in order to couple optical transmitters and optical receivers to the optical path. However, the use of the optical couplers causes considerable insertion loss which amounts to about 7dB between a transmitter and a receiver, and therefore, restricts the number of fanning-out points of the PON and the transmission distance. The optical couplers also give rise to reflection which causes crosstalk.

It is an object of the present invention to provide a two-way transmission system using a single optical path, wherein the insertion loss is reduced and the problem of reflection does not arise.

In accordance with the present invention, there is provided a transmission system comprising an optical path having a first end, a first optical transmitter, a first optical receiver, a first optical switch, coupled with the first end of the optical path, the first optical transmitter, and the first optical receiver, for selectively connecting one of the first optical transmitter and the first optical receiver to the first

end of the optical path, and a first controller, connected to the first optical switch, for controlling the first optical switch.

Figure 1 is a block diagram of a transmission system according to a first embodiment of the present invention;

Figures 2A to 2D are timing charts explaining an operation of the transmission system of Fig. 1;

Figure 3 is a cross-sectional view of an example of an optical switch;

Figure 4 is a block diagram of a transmission system according to another embodiment of the present invention;

Figures 5A to 5F are timing charts explaining an operation of the transmission system of Fig. 4; and

Figure 6 is a block diagram of a transmission system according to another embodiment of the present invention.

Figure 1 shows a construction of a transmission system according to an embodiment of the present invention. In Fig. 1, an optical fiber 10 is laid between a station 12 and a subscriber set 14. One end of the optical fiber 10 in the station 12 is coupled with one of three ports of an optical switch 16, and the other end of the optical fiber 10 in the subscriber set 14 is coupled with one of three ports of an optical switch 18. An optical transmitter 20 and an optical receiver 22 are coupled with the optical switch 16 at the remaining ports thereof. Similarly, an optical transmitter 24 and an optical receiver 26 are coupled with the optical switch 18 at the remaining ports thereof. The optical switch 16 is controlled by a controller 28, and the optical switch 18 is controlled by a controller 30.

Figures 2A to 2D are timing charts explaining an operation of the transmission system of Fig. 1. Fig. 2A, Fig. 2B, Fig. 2C and Fig. 2D show operation states of the optical switch 16, signals transmitted from and received by the station 12, signals received by and transmitted

from the subscriber set 14, and operation states of the optical switch 18, respectively.

As shown in Figs. 2A and 2D, the optical switches 16 and 18 are switched in synchronism with each other at constant intervals under control of the controller 28 and 30, respectively. During a period 32 of transmission from the station 12 to the subscriber set 14, the optical switch 16 is switched so that the optical transmitter 20 is coupled with the optical fiber 10, and the optical switch 18 is switched so that the optical receiver 26 is coupled with the optical fiber 10, as shown by solid lines in Fig. 1. During a period 34 of transmission from the subscriber set 14 to the station 12, the optical switch 16 is switched so that the optical receiver 22 is coupled with the optical fiber 10, and the optical switch 18 is switched so that the optical transmitter 24 is coupled with the optical fiber 10, as shown by broken lines in Fig. 1.

During the period 32, a signal 36 is transmitted from the optical transmitter 20 as shown in Fig. 2B, and the signal 36 arrives at the optical receiver 26 after a delay time Δ due to the optical fiber 10, as shown in Fig. 2C. After reception of the signal 36 is completed, the optical switches 16 and 18 are switched. While the optical switches 16 and 18 are set as shown by broken lines, a signal 38 is transmitted from the optical transmitter 24 as shown in Fig. 2C, and the signal 38 arrives at the optical receiver 22 after a delay time Δ as shown in Fig. 2B. After reception of the signal 38 is completed, the optical switches 16 and 18 are switched, and the period 32 of transmission from station 12 to the subscriber set 14 starts again. By repeating the above process, a time compression multiplexing (TCM) transmission using a single optical fiber is carried out.

Figure 3 shows an example of the optical switch 16 or 18. A prism 40 is located as shown in Fig. 3 and an optical path from an optical fiber 42, through a lens 44,

prism 40 and lens 46, to an optical fiber 48, is formed. The optical fiber 42 is thus optically coupled with the optical fiber 48. When the prism 40 is moved, by a electromagnetic drive mechanism, to a position where the prism 40 does not obstruct the optical path between the lens 44 and a lens 50, an optical path from the optical fiber 42, through the lenses 44 and 50, to an optical fiber 52 is formed and thus the optical fiber 42 is optically coupled with the optical fiber 52.

Optical switches such as a magneto-optical switch including YIG ($Y_3Fe_5O_{12}$) which changes its plane of polarization of polarized light in response to an applied magnetic field and an optical switch including lithium niobate ($LiNbO_3$) or GaAs semiconductor whose refractive index is changed in response to an applied electric field, may be used as the optical switched 16 and 18.

In the two-way transmission system according to the present invention, since optical switches which selectively couple one of two ports thereof with another port thereof are used, the insertion loss is improved and the problem of reflection does not arise.

Figure 4 shows a construction of a transmission system according to another embodiment of the present invention. If Fig. 4, a plurality of subscriber sets 54 are connected through a passive optical network (PON) to a station 58.

The station 58 includes an optical switch 60 connected to a root of the PON 56, a transmitter 62 connected to the optical switch 60, a receiver 64 connected to the optical switch 60 and a controller 66 controlling the optical switch 60, the transmitter 62 and the receiver 64. The subscriber set 54 includes an optical switch 68 connected to a branch of the PON 56, a transmitter 70 connected to the optical switch 68, a receiver 72 connected to the optical switch 68, and a controller 74 controlling the optical switch 68, the

transmitter 70 and the receiver 72.

Figures 5A to 5F are timing charts explaining an operation of the transmission system of Fig. 4. Fig. 5A, 5B, 5C, 5D, 5E and 5F show operation states of the optical switch 60, signals transmitted from and received by the station 58, operation states of the optical switch 68 in the 1-st subscriber set 54, signals received by and transmitted from the 1-st subscriber set 54, operation states of the optical switch 68 in the n-th subscriber set 54, and signals received by and transmitted from the n-th subscriber set 54, respectively.

While the optical switch 60 of the station 58 selects the transmitter 62 as shown in Fig. 5A, a series of channel signals #1, #2 ... #n preceded by a control signal 76 are transmitted from the transmitter 62, as shown in Fig. 5B, and are delivered via the PON 56 to the individual subscriber sets 54. The signals #1, #2 ... #n arrive at the individual subscriber sets 54 after definite delay times $\Delta 1$, $\Delta 2$ ... Δn which are dependent on distances between the station 58 and the subscriber sets 54, as shown in Figs. 5D and 5F. The channel assignment to each subscriber set is determined according to order of distance, i.e., $\Delta 1 < \Delta 2 \ldots < \Delta n$. In each of the subscriber sets 54, a channel signal assigned to the subscriber is selected according to the control signal 76 and is received.

As shown in Fig. 5A, the optical switch 60 is switched to select the receiver 64 a predetermined time interval after the last channel signal #n has been transmitted. The time interval is determined considering round-trip time $2\Delta n$ for the farthest subscriber. In this period, signals #1', #2' ... #n' each preceded by control signals 78 are transmitted from each subscriber set 54 to the station 58, as shown in Figs. 5D and 5F. The signals #1', #2' ... #n' join at junction points of the PON 56, and arrive at the station 58 in order of #1',

#2', ... #n', as shown in Fig. 5B. After the last signal #n' arrives, the optical switch 58 is again switched to select the transmitter 62. By repeating the above process, time division multiple access (TDMA) transmission using a PON is carried out.

Figure 6 shows a construction of a transmission system according to another embodiment of the present invention. In Fig. 6, a station 80 and a subscriber set 82 which is a representative of subscriber sets connected via a PON 84 to the station 80, are shown. The station 80 includes an optical switch 86 connected to the PON 84, an electric/optical conversion circuit 88 connected to the optical switch 86, a frame generation circuit 90 connected to the electric/optical conversion circuit 88, an overhead bit insertion circuit 92 connected to the frame generation circuit 90, an optical/electric conversion circuit 94 connected to the optical switch 86, a frame synchronization circuit 96 connected to the optical/electric conversion circuit 94, and a controller 98 connected to the overhead bit insertion circuit 92, the frame generation circuit 90, and the optical switch 86. The overhead bit insertion circuit 92, the frame generation circuit 90 and the electric/optical conversion circuit 88 constitute a transmission section 99, and the frame synchronization circuit 96 and the optical/electric conversion circuit 94 constitute a receiver section 100. The subscriber set 82 includes an optical switch 102, an electric/optical conversion circuit 104 connected to the optical switch 102, a frame generation circuit 106 connected to the electrical/optical conversion circuit 104, an optical/electrical conversion circuit 108 connected to the optical switch 102, a frame synchronization circuit 110 connected to the optical/electric conversion circuit 108, an overhead bit detection circuit 112 connected to the frame synchronization circuit 110, and a controller connected to the optical switch 102, the frame

generator 106 and the overhead bit detection circuit 112. The electric/optical conversion circuit 104 and the frame generation circuit 106 constitute a transmission section 116, and the optical/electrical conversion circuit 108, the frame synchronization circuit 110 and the overhead bit detection circuit 112 constitute a receiver section 118.

In the station 80, upon being powered-on, the controller 98 generates an optical switch switching signal having a constant period. While the optical switch 86 is switched to a transmitter (corresponding to a connection shown by a solid line), overhead bits are inserted into transmission signals in the overhead bit insertion circuit 92. The transmission signals including the overhead bits are frame-synchronized in the frame generation circuit 90, and are converted into optical signals in the electric/optical conversion circuit 88. As mentioned above, the optical signals transmitted through the optical switch 86 and the PON 84 to the individual subscribers include control signals as the overhead bits.

In the subscriber set 82, upon being powered-on, the optical switch 102 is fixed to a receiver side (corresponding to a connection shown by a solid line). The optical signals received from the station 80 are converted into electric signals in the optical/electric conversion circuit 108. Frame synchronizm in the electric signals is established in the frame synchronization circuit 110, and the overhead bits are detected in the overhead bit detection circuit 112. The subscriber set 82 maintains the reception operation until all of the subscriber sets complete reception. After completion of reception in all of the subscriber sets, the optical switch 102 is switched to transmission (corresponding to a connection shown by a broken line) in synchronizm with an operation of the station 80 by driving the controller 114 according to the overhead

bits. At this time, since the optical switch 86 in the station 80 has been already switched to a receiver side (corresponding to a connection shown by a broken line), the station 80 is ready to receive signals from the subscriber sets. The subscriber sets transmit signals accompanied by control signals within time slots assigned to each subscriber, one by one, and the transmission signals arrive at the station 80 in a predetermined order. This situation is similar to that explained with reference to Figs. 5A to 5F.

Although the length of time slots assigned to the individual subscribers are not mentioned in the above description, all the subscribers may of course use the same length of time slots, i.e., the same transmission capacity may be assigned to all the subscribers, but a time slot longer than others may be assigned to a specific subscriber. In addition, the transmission path is not limited to the optical fiber, but the present invention may be similarly applicable to an optical space transmission system.

Claims:

1. A unit for a transmission system including an optical path, the unit comprising an optical transmitter, an optical receiver, and an optical switch for selectively connecting the optical transmitter or the optical receiver to an end of the optical path, and a controller connected to the optical switch, for controlling the optical switch.

2. A two-way transmission system including at least two units according to claim 1, and an optical path comprising a single optical fiber, connecting these two units.

3. A transmission system according to claim 2 and including a means for synchronising the optical switches so that a connection between the optical transmitter of one unit and the optical receiver of a second unit, and a connection between the optical transmitter of the first unit and the optical receiver of the second unit via the optical fiber are alternately formed.

4. A transmission system according to claim 3 and adapted for time compression multiplexing transmission via the optical fiber between one unit acting as a station at one end of the optical fiber and another unit acting as a subscriber at the other end of the optical fiber.

5. A transmission system including several units according to claim 1, and an optical path comprising a passive optical network, wherein one unit is located at the root of the passive optical network and further units are each located at one of the branches of the passive optical network.

6. A transmission system according to claim 5 and including a means for synchronising the optical switches so that connections between the optical transmitter of the unit located at the root of the

optical network and the optical receivers of the units located at the branches of the optical network and a connection between the optical transmitters of the units located at the branches of the optical network and the optical receiver of the unit located at the root of the optical network are alternately formed.

7. A transmission system according to claim 6, and adapted for time division multiple access between one unit acting as a station at the root of the passive optical network and further units acting as subscribers at the branches of the passive optical network.

8. A method of transmission between at least two units connected via an optical path, the units each comprising an optical transmitter, an optical receiver, an optical switch and a means of controlling the optical switch, the method comprising the steps of selectively connecting the optical transmitter and the optical receiver of each unit to the optical path by means of the optical switches and synchronising the optical switches so that connections are alternately made between the optical transmitter of a first unit and the optical receiver of a second unit, on the one hand, and the optical receiver of the first unit and the optical transmitter of the second unit, on the other hand.

9. A transmission system substantially as described herein with reference to any of the accompanying figures.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

-11-

Relevant Technical Fields	Application number GB 9401632.6
(i) UK Cl (Ed.M) H4B (BK2, BK24, BN); G2J (JGEE, JBSS1) (ii) Int Cl (Ed.5) H04B 10/02, 10/24; H04Q 11/00	Search Examiner DR E PLUMMER
	Date of completion of Search 22 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- ALL

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1461362	(BAC) Whole document	1
X	US 5077813	(CARL ZEISS) eg. Abstract	1, 2
X	US 4551829	(HARRIS CORP) NB. Switches 31, 81; Figure 1	1-4, 8

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).